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Pulsars in FIRST Observations

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Abstract We identified 16 pulsars from the Faint Images of the Radio Sky at Twenty-cm (FIRST) at 1.4 GHz. Their positions and total flux densities are extracted from the FIRST catalog. Comparing the source positions with those in the PSR catalog, we obtained better determined positions of PSRs J1022+1001, J1518+4904, J1652+2651, and proper motion upper limits of another three pulsars PSRs J0751+1807, J1012+5307, J1640+2224. Proper motions of the other 10 pulsars are consistent with the values in the catalog.

Key words: pulsar – proper motion – position – flux density

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1 INTRODUCTION

Pulsars obtain a large kick velocity during their birth. Therefore pulsars moved away from their birth place, which is believed to be the center of supernova remnant. Measuring the proper motion of pulsars can derive an independent measurment of pulsar age, which has a number of astrophysical usages. For example, studies of the evolution of neutron star magnetic fields and pulsar emission beam.

There are three methods to measure proper motions: (1) traditional optical methods, (2) timing measurements, and (3) interferometric measurements. The first technique is applied to a few pulsars which can be seen in optical wavelengh (Mignani et al. 2000). Pulsar proper motions can be obtained from regular timing observations carried out over a sufficiently long interval. However, timing noise restricts its usefulness except millisecond pulsars (Kaspi, Taylor & Ryba 1994; Bell et al.1995; Nice & Taylor 1995; Wolszczan et al. 2000). Interferometric observations measure the angular transverse motions of the

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pulsars in the sky, relative to a set of reference sources (e.g. McGary et al. 2001). This technique is the most productive methods for determing proper motions of pulsars so far.

FIRST (Becker et al. 1995) is a project designed to produce the radio equivalent of the Palomar Observatory Sky Survey over 10,000 square degrees of the North Galactic Cap —– using B-configuration of NRAO Very Large Array (VLA) at 1.4 GHz. The observations have a resolution of $5''$, and the positional accuracies have 90% confidence error circles of radius $<0.5''$ at the 3 mJy level and $1''$ at the detected threshold 1 mJy.

We have tried to identify the pulsars from the FIRST catalog, and then to investigate their proper motions.

2 IDENTIFICATIONS

Only 42 known pulsars listed in PSR catalog are located in the sky region covered by the FIRST. We searched for radio sources in the FIRST catalog within $30''$ around each pulsar, and 17 radio sources have been found. At the 1 mJy threshold, FIRST detected ~ 90 sources per square degree. The probability for chance coincidence in the region of $30''$ angular radius is about 0.6%. We noticed that pulsar positions in PSR catalog and in FIRST survey are at different epochs. If a pulsar has a large proper motion, e.g. 400 mas per year (the largest known), then after 30 years, the position offset would be $12''$. So, $30''$ area should not miss any known pulsar if it is detectable by the FIRST.

Position of pulsars from PSR catalog generally have a typical positional uncertainty better than $0.1''$, but occasionally up to a few arcsec for newly discovered pulsars. The 17 sources are listed in Table 1 with PSR Jnames in column 1, their positions in column 2 and column 3 with uncertainties in brackets, the epochs for the position and flux densities at 1.4 GHz from PSR catalog in column 4 and column 5, respectly. For comparison, we also list their parameters from the FIRST survey in Table 1: the positions in column 6 and 7, the positional uncetainties in column 8, the flux densities in column 10.

The sky region of FIRST survey was done over a long period, from 1994 to 1999 and had no accurate epoch listed in the FIRST catalog, so we estimated the approximate epoch year by the color displayed in the images given in the FIRST observations, and took MJD in the middle of each year as the approximate observation epoch (column 9 in Table 1). This should be fine for proper motion discussions considering the position uncertainties of the FIRST sources listed in Table1.

13 pulsars were identified (in Table 1 except J1115+5030) by comparing the peak flux densities of sources between the FIRST and PSR catalog. The consistency of the pulsar flux densities between the two catalogs is showed in Figure 1.

3 DISCUSSION

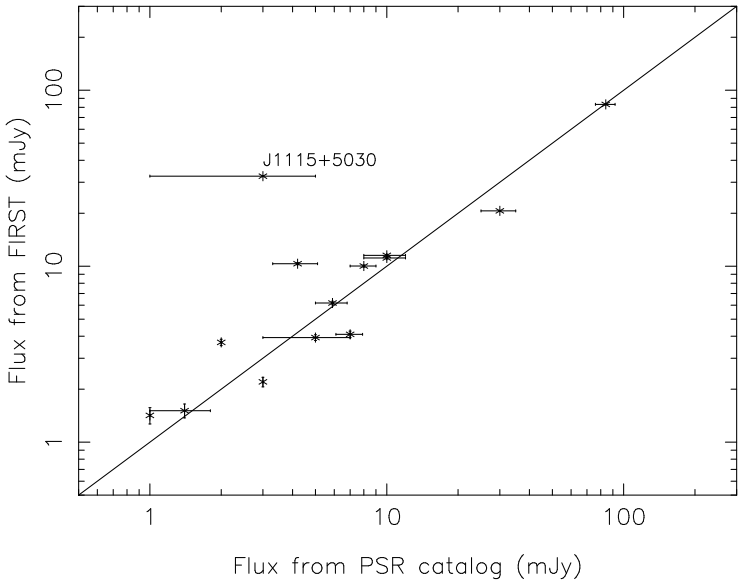

Fig. 1 Comparison of pulsar flux densities from the PSR catalog and the FIRST measurement

3.1 Undetected Pulsars

VLA measurements of the flux densities at 1.4 GHz of most identified pulsars are comparable to the flux densities listed in PSR catalog. PSR J1115+5030 has a flux density of 32.50 mJy in FIRST but 3 mJy in PSR catalog (Fig. 1), and its position offset is $12''.17$. If so, we obtained its proper motion $\mu_\alpha cos\delta$=-73 ± 24 mas yr^{-1}, μ_δ=691 ± 24 mas yr^{-1}, which are much larger than those listed in PSR catalog, $\mu_\alpha cos\delta$=-22 ± 3 mas yr^{-1}, μ_δ=-51 ± 3 mas yr^{-1}. So, we think the FIRST source is probably chance coincident, and the pulsar was not detected in the survey.

Most of the undetected pulsars may be either lower than survey threshold 1 mJy or influenced by the interstellar scintillation (e.g. Gupta et al. 1994) which both helps and hinders the detections (Cordes & Lazio 1991). In table 2, we listed those pulsars with flux densities larger than the threshold 1 mJy but did not detected in FIRST survey.

3.2 Flux Densities, Positions and Proper Motions

We can see from Table 1 that PSR J1518+4904, J1640+2224, J1652+2651 have no flux densities listed in PSR catalog. We believe the flux densities and the positions in FIRST are more reliable than those in PSR catalog. Much accurate positions for three pulsars J1022+1001, J1518+4904 and J1652+2651 (see Table 1) can be used.

The position derived from the FIRST observations were compared with those of pulsars in PSR catalog and the proper motions were calculated if possible. The results are listed in Table 3. Proper motions in right ascension and declination direction available in the PSR catalog are also listed in column 2 and 3 for comparison. Columns 4 and 5 gave

the position offsets. Proper motions or upper limits we obtained are listed in columns 6 and 7. We obtained the upper limits of proper motions for other 3 pulsars PSRs J0751+1807, J1012+5307, J1640+2224. The proper motions of 10 pulsars are consistent well with those listed in PSR catalog (Fig. 2).

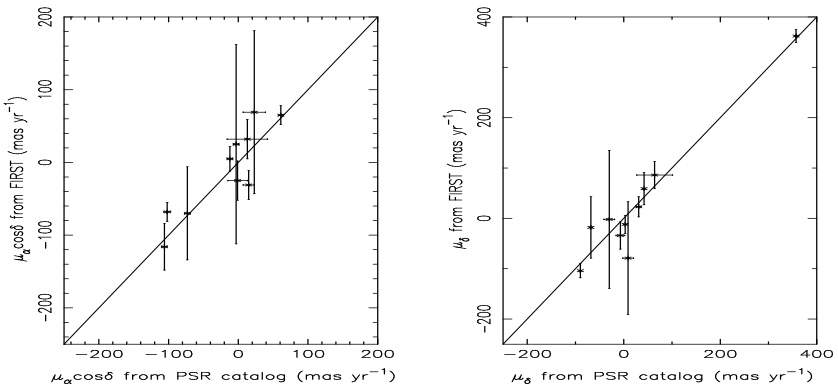

Fig. 2 Comparison of pulsar proper motions in ascension (left) and declination (right) directions listed in the PSR catalog and derived from FIRST

4 SUMMARY

In the sky region covered by the FIRST, 17 sources near pulsar positions have been found. In the following, we compared the pulsar positions and flux densities from the FIRST with those from the PSR catalog (updated version of Taylor et al. 1993). We obtained new flux densities of 6 pulsars and much accurate positions of 3 pulsars PSRs J1022+1001, JJ1518+4904, J1652+2651. For 10 pulsars, we obtained their proper motion values consistent with those in PSR catalog, and for other 3 pulsars, proper motion upper limits were obtained.

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Table 1 Pulsar positions and flux densities from the PSR catalog and the values of nearby FIRST sources within 30″

PSR	RA (2000)	DEC (2000)	Epoch	Flux	RA (first)	DEC (first)	σ	Epoch	Flux
Jname	*h m s*	° ′ ″	MJD	mJy	*h m s*	° ′ ″		MJD	mJy
0751+1807	07 51 09.1582(7)	+18 07 38.71(5)	49301	1	07 51 09.148	+18 07 38.72	0.89	50996	1.42±0.151
0826+2637	08 26 51.310(2)	+26 37 25.57(7)	40264	10(2)	08 26 51.438	+26 37 22.83	0.35	49901	11.14±0.135
0922+0638	09 22 13.977(3)	+06 38 21.69(4)	46573	4.2(9)	09 22 14.005	+06 38 22.82	0.36	51361	10.33±0.139
0943+1631	09 43 30.042(4)	+16 31 35.49(6)	47555	1.4(4)	09 43 30.092	+16 31 34.67	1.17	51361	1.51±0.137
0953+0755	09 53 09.316(3)	+07 55 35.60(4)	46058	84(8)	09 53 09.286	+07 55 35.94	0.28	51361	83.13±0.153
1012+5307	10 12 33.4326(4)	+53 07 02.66(1)	49220	3	10 12 33.387	+53 07 02.09	0.63	50631	2.20±0.138
1022+1001	10 22 58.06(6)	+10 01 54(3)	49780	2	*10 22 58.015*	*+10 01 52.84*	0.54	51361	3.69±0.153
1115+5030	11 15 38.35(2)	+50 30 13.6(3)	44240	3(2)	11 15 38.483	+50 30 25.70	0.30	50631	32.50±0.142
1136+1551	11 36 03.296(4)	+15 51 00.7(1)	42364	30(5)	11 36 03.180	+15 51 09.62	0.31	51361	20.62±0.136
1239+2453	12 39 40.475(3)	+24 53 49.25(3)	46058	10(2)	12 39 40.386	+24 53 49.87	0.34	49901	11.53±0.145
1509+5531	15 09 25.724(9)	+55 31 33.01(8)	48383	8.0(10)	15 09 25.674	+55 31 32.90	0.37	50631	10.02±0.146
1518+4904	15 18 16.6(1)	+49 04 35(1)	49896		*15 18 16.832*	*+49 04 34.19*	0.45	50631	5.03±0.127
1543+0929	15 43 38.826(6)	+09 29 16.8(2)	42304	5.9(9)	15 43 38.835	+09 29 16.50	0.41	51361	6.18±0.146
1607−0032	16 07 12.117(2)	−00 32 40.18(6)	42307	5(2)	16 07 12.078	−00 32 40.98	0.63	50996	3.93±0.148
1640+2224	16 40 16.7417(1)	+22 24 09.015(3)	49360		16 40 16.698	+22 24 08.98	0.87	50996	1.92±0.150
1652+2651	16 52 03.0(3)	+26 51 40(1)	49800		*16 52 03.080*	*+26 51 39.85*	0.39	49901	6.27±0.143
2145−0750	21 45 50.4693(2)	−07 50 18.34(1)	48979	7.0(9)	21 45 50.477	−07 50 18.35	0.62	50631	4.10±0.175

Table 2 Pulsars which should be detected by FIRST but not

PSR	RA	DEC	1.4 GHz
Jname	*h m s*	° ′ ″	mJy
0823+0159	08:23:09.76(1)	+01:59:12.8(5)	1.5(7)
0837+0610	08:37:05.649(3)	+06:10:14.08(5)	4.0(10)

Table 3 Pulsar proper motions or upper limits

PSR	$\mu_\alpha cos\delta$	μ_δ	ΔRA	ΔDEC	$\mu_\alpha cos\delta$	μ_δ	Notes
Jname	mas yr^{-1}	mas yr^{-1}	$''$	$''$	mas yr^{-1}	mas yr^{-1}	
0751+1807	...	...	−0.15±0.89	0.01±0.89	-31 ± 191	2 ± 192	pm upper limit
0826+2637	61±3	−90±2	1.73±0.35	−2.74±0.36	65 ± 13	-104 ± 14	pm consistent
0922+0638	13±9	64±37	0.42±0.36	1.13±0.36	32 ± 27	86 ± 27	pm consistent
0943+1631	23±16	9±11	0.72±1.17	−0.82±1.17	69 ± 112	-79 ± 112	pm consistent
0953+0755	15±8	31±5	−0.45±0.29	0.34±0.29	-31 ± 20	23 ± 20	pm consistent
1012+5307	...	...	−0.41±0.63	−0.57±0.63	-106 ± 163	-147 ± 163	pm upper limits
1022+1001	...	...	−0.66±1.05	−1.16±3.05	...	...	new position
1115+5030	22±3	−51±3	−1.28±0.42	12.10±0.42	...	...	no detection
1136+1551	−102±5	357±3	−1.68±0.32	8.92±0.33	$\mathbf{-68 \pm 13}$	362 ± 13	pm consistent
1239+2453	−106±4	42±3	−1.22±0.34	0.62±0.34	-116 ± 32	59 ± 32	pm consistent
1509+5531	−73±4	−68±3	−0.43±0.39	−0.11±0.38	-70 ± 64	-18 ± 61	pm consistent
1518+4904	...	...	2.28±1.57	−0.81±1.10	...	...	new position
1543+0929	−12±4	3±3	0.13±0.42	−0.30±0.45	5 ± 17	-12 ± 18	pm consistent
1607−0032	−1.0±14	−7±9	−0.58±0.63	−0.80±0.63	-25 ± 27	-34 ± 27	pm consistent
1640+2224	...	...	−0.61±0.87	−0.04±0.87	-136 ± 193	-8 ± 193	pm upper limits
1652+2651	...	...	1.08±4.52	−0.15±1.07	...	...	new position
2145−0750	−3±4	−30±11	0.11±0.62	−0.01±0.62	25 ± 137	-2 ± 137	pm consistent

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